Planning ahead with FIESTA

RIU

Validated RNRRS Output.

A new highly detailed computer model of climate, land and water interactions is now available that covers the whole of the tropics. The model, known as FIESTA, can help us to better understand the effects of land use changes and climate change on hydrological systems and poor users downstream. FIESTA can be used to help decision makers apply watershed protection in appropriate areas, build water-related infrastructure and target efforts to get water to people who need it. The model is unique because it looks at areas as small as one square kilometre. This helps planners account for the very different hydrological effects that land use or climate change can have from area to area at a very local level—boosting our ability to develop sustainable land and water strategies.

Project Ref: **FRP30:**
Topic: **4. Better Water Harvesting, Catchment Management & Environments**
Lead Organisation: **Kings College, London, UK**
Source: **Forestry Research Programme**

Document Contents:

Description

Research into Use
NR International
Park House
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UK

Geographical regions included:

Brazil, Central America, Colombia, Ecuador,

Target Audiences for this content:

Forest-dependent poor,

FRP30

A. Description of the research output(s)

1. Working title of output or cluster of outputs.

FIESTA (Fog Interception for the Enhancement of Streamflow in Tropical Areas) Fog delivery model

In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

FIESTA - a pan-tropical, spatially detailed decision support tool for managing land use and climate change impacts on water

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.

Forestry Research Programme

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RIUP activities.

Hydrological impacts of converting tropical montane cloud forest to pasture, with initial reference to northern Costa Rica. : DfID R7991 led by L.A. Bruijnzeel (Free University of Amsterdam) based on the work of Reto Burkard, Alexander Carvajal, Arnoud Frumau (Free University of Amsterdam), Lars Köhler, Mark Mulligan (King's College London), Jaap Schellekens (Free University of Amsterdam) wth the assistance of: Sophia Burke (AMBIOTEK), Julio Calvo, Jorge Fallas, Gemma Duno-Denti (AMBIOTEK), Robert Figueras (AMBIOTEK) , Lieselotte Tolk, and Michiel Zijp Incorporating the FIESTA_delivery model : led by Mark Mulligan (King's College London) with Sophia Burke (AMBIOTEK) http://www.ambiotek.com/fiesta

Global cloud forests and environmental change in a hydrological context DfID ZF0216 led by Mark Mulligan (King's College London) with Sophia Burke (AMBIOTEK). http://www.ambiotek.com/cloudforests

4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? ***(max. 400 words)****. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output when held in a database.*

Output:
FIESTA is a spatially-detailed computer **model** of **climate, land and water interactions** covering the **entire tropics** at a spatial resolution of 1km and using the best available satellite and ground derived databases as the basis for understanding the spatial distribution of **water resources** *and* the likely impact of scenarios for **land use change** and **climate change** upon them. The system propagates impacts downstream, connecting hydrological system responses to land use or climate

change with their cumulative impacts on **downstream populations**.

Limited access to sufficient, high quality **water** in all seasons is a major contributing factor to poverty and restricted development in many parts of the tropics. Water has impacts on agricultural productivity and food processing, on transport infrastructures and access to markets, on industrial potential and on hygiene, health and disease as well as soil and ecological degradation. With increasingly urbanised populations the availability of stable, high volume supplies of water become all the more critical.

Lack of detailed, locally-specific information concerning impact on the **provision of water** as an environmental service of actual and proposed land use and cover change is a major impediment to the development of sustainable land and water management strategies (including **payments for environmental services** - PES - schemes). This deficiency is also an impediment to the appropriate **geographical targeting** of **watershed protection**, hydro-infrastructural developments and **water-poverty** alleviation. In order to properly assess the beneficiaries of watershed protection towards the development of **fair and appropriate PES policies**, one needs both spatial detail and a national to international extent for analysis of comparative and downstream hydrological impacts. Single-catchment studies are necessary but are not sufficient. Until FIESTA such information has never been available.

The FIESTA technique moves away from previous 'one size fits all' characterisations of climate-land-water relationships to an approach in which the inherent geographic uniqueness of areas is accounted for. The results indicate that, even areas separated by only 1km, can show very different hydrological impacts of land use and climate change, according to their geographic (topographic, climatic, ecological and socioeconomic) conditions. Decision-making '**rules of thumb**' concerning the impacts of afforestation, deforestation or other developments on water resources are thus not appropriate and decisions have to be made on the basis the **locally specific** hydrological responses. Poor tropical countries do not have such information. The FIESTA approach provides it for the entire tropics - alongside a series of **scenario analysis** options for investigating the **downstream impacts** of specific land use change policies and climate change futures.

In DfID terminology FIESTA can be classified as '**enabling'**. Although it does not address the needs of the poorest people in a direct manner, the information and tools generated by the project contribute to optimum (upland) forest and water management in the humid tropics. The FIESTA_delivery model in particular has assisted in broadly identifying hydrological 'wet spots' and likely changes in site water budgets (and their downstream propagation) associated with forest conversion to pasture (or the reverse), as well as of the effects of longer term climate change across the region.

The FIESTA_delivery model was produced in 2005/6 as part of the modelling effort of the project 'Hydrological impacts of converting tropical montane cloud forest to pasture, with initial reference to northern Costa Rica' (DfID R7991)

5. What is the type of output(s) being described here?

Please tick one or more of the following options.

Product	Technology	Service	Process or Methodology	Policy	Other Please specify
	X		X		

6. What is the main commodity (ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment

Water

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options. Leave blank if not applicable

Semi-Arid	High potential	Hillsides	Forest-Agriculture	Peri-urban	Land water	Tropical moist forest	Cross-cutting
X		X	X		X	X	X

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	Irrigated	Wetland rice based	Smallholder rainfed highland	Smallholder rainfed dry/cold	Dualistic	Coastal artisanal fishing
X	X	X	X	X	X	

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words**).*

FIESTA_delivery is a detailed spatial decision support system for land and water management in the tropics. In order to add value and remove constraints to use one has to work on (a) its relations with other projects that look at land-water interactions from different perspectives (e.g. R7937 and R8171) and with other tools, (b) facilitate uptake in the decision making process by combining with project outputs focused on other (non-water) aspects of forest and land management (e.g. R5651 R6348 R7315, R8525 and R6320 (R7274), (c) further develop the management aspects of the system to incorporate work on management other than through land use planning and forest protection for example incorporating rainwater harvesting and other techniques (R7888) and (d) couple the system more tightly with socio-economic analyses of the efficacy of payments for environmental services schemes (see for example project R8174).

Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.

R6320 (R7274) Sustainable community forest management Chiapas, Mexico
R6914 Analysis of stakeholder participation costs
R5651 R6348 R7315 Integrated use of agroforestry models
R7937 Resource focused catchment management
R8171 Low base flows in dry forest areas
R8525 Hillside products in Bolivia
R7888 Rainwater harvesting and management
R8174 Can markets for environmental services contribute to poverty reduction?

Validation

B. Validation of the research output(s)

*10. **How** were the output(s) validated and **who** validated them?*

Evidence that the FIESTA_delivery approach has proven to be effective to beneficiaries, other researchers, and policy advisors include the following:

(a) **Policy networks :** The work contributed to a major DfID FRP policy brief - “From the Mountain to the Tap” (FMTT) which was widely publicised in the press and policy worlds. Though the messages to come out of FMTT were oversimplified, some subsequent articles and some press coverage were much more focused on the important spatial variability of the impacts of trees on water and thus focused the need to move away from simple rules of thumb applied over entire, heterogeneous regions towards a more scientific approach. Preliminary research results were presented by various team members at the International Symposium on Science for Conservation and Management of Tropical Montane Cloud Forests, held in Hawaii, 27 July – 1 August 2004. This symposium drew together representatives from various scientific disciplines (mostly ecology and hydrology but also environmental economics and sociology), forest and park managers, and representatives of NGOs dealing with sustainable development and community participation, many from Latin America. The proceedings of the Symposium are expected to constitute a landmark publication on cloud forest hydrology and are to be published in autumn 2007. A special effort has been made to reach environmental economists through several electronic newsletters (notably Flows-on line / News on Payments for Watershed Services by S. Tognetti). Finally, project activities and results were highlighted in the BBC Radio4 Documentary ‘Costing the Earth’ which was broadcast at 9 p.m. on 1 December 2005 (see http://www.bbc.co.uk/radio4/science/costingtheearth_20051201.shtml). In September 2006 Dr. Bruijnzeel presented some of the results at a meeting of the World Bank and Conservation International is Washington DC, USA.

(b) **Policy advisors :** The FIESTA system has been demonstrated during a series of training courses with policy advisors, held in San José, Costa Rica. The meeting was attended by over 60 invited participants representing the full spectrum of Costa Rican institutions dealing with forest and water issues, including ICE, various universities and Ministries, and several NGO’s operating Payments for Environmental Services schemes (see Annex 13 for a listing of institutions). In addition, there were representatives from other countries in the region (Colombia, Ecuador, Guatemala, Mexico, Perú and Venezuela). All materials were

made available in both English and Spanish. A group of 18 people representing key institutions from Costa Rica and throughout tropical America attended the subsequent training workshop on the use and application of the FIESTA models. Subsequent training workshops showcasing the FIESTA_delivery model have been held at the Institute for Amazon Studies (INPA), Brazil and the Copernicus Institute for Sustainable Development (Netherlands).

(c) **Other scientists :** The models and project results are frequently used in masters level training in the Hydrology programme of the Free University of Amsterdam and the Environmental Modelling programme at King's College London. A project website has existed since March 2004 (www.geo.vu.nl/~fiesta) incorporating project summaries, reports and theses. The 1 km and 90m versions of the FIESTSA_delivery model and all associated datasets for Costa Rica are available from the AMBIOTEK website: http://www.ambiotek.com/fiesta. Interactive Google Earth- based visualisations of the model results for Costa Rica (90m) and the whole of Central America (1km) are available to anyone with access to the internet. The model and associated reports receive downloads from around 300 different organisations per month. Moreover, the model has been used recently by the UNEP ARK 2010 project to assess hydrological impacts of land use and climate change for catchments flowing into the major dams of Colombia and Ecuador as a test of protocol for future larger scale initiatives.

Various evidence indicates that the results, tools and policy implications are being taken up in the relevant communities but no study has been carried out to assess this formally.

*11. **Where and when** have the output(s) been validated?*

*Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above **(max 300 words)**.*

The system provided its most direct inputs to policy in Costa Rica's montane hillside systems at the forest-pasture boundary in 2005./6. In some cases these systems are smallholder led but the main beneficiary has been hydro-electric companies, particularly the Costa Rican National Electricity Institute (ICE) who have been able to use the science and models produced, in their evaluation of alternatives to the operational PES scheme in Costa Rica.

The models have also been applied in Guatamala, Honduras, Mexico, Nicaragua, Panama, Colombia, Ecuador and Brazil but their impact on policy is not known since these validations have all occurred post-project. Whilst there are reports that the recommendations of the project published in FMTT have been taken up elsewhere, there is no hard evidence for this.

Current Situation

C. Current situation

*12. **How and by whom** are the outputs currently being used? Please give a brief description **(max. 250 words**).*

Directly by ICE (the Costa Rican National Electricity Institute) and indirectly smaller hydro-power and forest conservation communities in Costa Rica and throughout central America as sources of much needed spatial data on water inputs and science based recommendation on the value of cloud forests.

By various high level conservation and policy organisations who have taken on board the messages of the project (including the World Bank, Conservation International, UNEP-WCMC in their ARK 2010 project) and are using them to inform water-related decision making in relation to tropical (montane) forests.

By the Institute for Amazon Studies for training in impacts of forest cover change in the Amazon Basin and its peripheral upland forests.

By universities as training materials in forest hydrology.

*13. **Where** are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used **(max. 250 words).***

Guatemala, Honduras, Mexico, Nicaragua, Panama, Colombia, Ecuador and Brazil

*14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading **(max 250 words).***

The only measure we have of this is the frequency of download of the FIESTA_delivery model from http://www.ambiotek.com/fiesta which remains at a fairly constant 300 downloads per month. This suggests that use is still spreading. Downloads occur from all over the world (developed and developing countries) not only from the target countries in which the model has been applied.

*15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key facts of success? **(max 350 words).***

Few programmes, platforms and structures exist that have assisted with the promotion or adoption of the outputs. Promotion has been largely within the context of activities within the original DfID project (the training workshops) and subsequent scientific presentations invited by international conservation, education, scientific or policy related organisations. The website remains an important dissemination tool for this kind of output. Key aspects to success of the project have been its robust, scientific approach, which was sufficiently detailed and sophisticated to tackle fully the scientific issue at the heart of the problem and to do this in a spatially realistic manner. Other aspects have included the development of a generically applicable model that could be applied in other areas but which makes few assumptions about the conditions existing in those areas - rather it relies on hard data to specify the actual conditions. Finally - and most importantly - the model is based on freely available software, uses freely available spatial data that is near-global in coverage (and thus one does not require a field data collection programme to provide local data for the model, though if local data are available they can be

used). The model also operates at policy relevant scales (national to continental) and provides results spatially as maps indicating where land use and climate change will have positive hydrological effects and where it will have negative ones. Finally these effects are cumulated downstream so that off-site as well as on-site impacts are clear.

Current Promotion

D. Current promotion/uptake pathways

*16. **Where** is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion **(max 200 words).***

Promotion is carried out only by the project sponsors (DfID) via their website and by the project leader and model developers through the production of articles, scientific papers, presentations and the maintenance of websites and information systems.

*17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. **(max 200 words)**.*

The output is a decision support system. It has been designed for application with routinely available data throughout the tropics and providing locally specific, detailed information on the hydrological impacts of particular scenarios for land use and climate change. The barriers to uptake are technical, infrastructural and concerning communication and marketing. Specifically these barriers can be stated as :

(a) The model is capable of running on datasets for the entire tropics. Though all of the datasets required are pan-tropical in extent and freely accessible (mainly satellite derived), they come from various organisations in various formats and require some considerable processing in order to prepare for a new area. This is an obstacle to users ability to apply the model to their specific area of interest if it is not in an area in which the datasets have already been processed for the model (central and South America).
(b) There are technical barriers to the uptake of the tools including slow internet connections and computing requirements and incompatibilities as well as communication barriers between sometimes complex model results requiring some knowledge of hydrological processes- and their understanding by policy advisors who may not be hydrological specialists. Though these effects are minimised in FIESTA_delivery, they are still an issue.
(c) Web based marketing and top down dissemination are limited in their filtration down through the hierarchies to the technicians who advise policy since higher levels in the policy hierarchy tend to prefer working with long established and thus trusted methodologies and tools, even if they have been superseded by better approaches. Moreover, uptake of sophisticated new tools even if they are well presented - as is the case with FIESTA - requires some level of one to one training at least to start the learning process. Training workshops in other countries/regions would greatly facilitate uptake of the tools in those areas.

18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues ***(max 200 words).***

Addressing the barriers in the same order as for question 17:

(a) **Data constraints :** Though datasets have been developed and provided for all of central America, Colombia and Ecuador they have not been provided in a common format for the rest of the tropics (though they are available in native formats from the variety of original data producers). Doing this would enable anyone to download the model and the data to run it for their region of interest and thereby use it for the development of much more locally relevant knowledge and policy support in the area of land and water management rather than rely on generic rules of thumb generated from work at other sites. This is a simple, technical data processing and database production exercise. AMBIOTEK and King's College London have considerable experience in making such global datasets readily available to anyone who might need to use them (see http://www.ambiotek.com/1kmrainfall and links therefrom for examples).

(b) **Technical barriers** : A version of the model capable of running online (rather than having to be downloaded, installed and run) and also providing its outputs to users in a familiar and easy to visualise form such as Google Earth overlays would go a long way towards breaking down the technical barriers to running these kinds of models and the communication barriers to visualising and understanding their outputs. Such a system could provide results pan-tropically but in a locally detailed manner and even be disseminated by the Intergovernmental Group on Earth Observations (GEO) which distributes spatial environmental data freely via satellite to anyone with a satellite dish, standard DVB-type receiver and a television, obviating the need for expensive computers, operating systems, fast internet connections or knowledge of computer use. Such a system would increase the audience of FIESTA tools to much smaller organisations who may not have technical departments or Geographical Information System (GIS) units.

(c) **Marketing and training barriers :** The Latin American training workshops have been very successful in facilitating the use of the models in the target countries and by those responsible for land and water policy. Replicating these throughout the montane-affected tropics in Africa and Asia would facilitate the same level of uptake in these regions and application of the tools to quite different (and often much more serious) problems of water management in the drier parts of these regions. Particularly relevant DfiD PSA countries in which to do this (where montane forests are highly threatened and yet are likely to contribute significantly to the seasonal or annual water availability in drier lowlands) include : Ethiopia, Kenya, Tanzania, Rwanda, DR Congo, Zambia, Zimbabwe, Mozambique, Malawi, Lesotho, China, Indonesia and Vietnam.

In the end much more accurate and detailed data and models are now available for watershed based land and water management in the tropics than are generally in use. Further validation will have to make these data and tools available in a form that is most appropriate to the changing needs of a range of end-users and will have to prove through experience that users should move from long established methods to these now well developed but relatively new ones.

19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

The outputs are not intended to be used by poor people but rather by those who would be responsible for land use planning and water resources management on behalf of those people :

from international donor agencies and NGOs, through governments to regional and local public and private sector stakeholders. Land use planning decisions by these agencies have significant impacts on the water-poverty of communities downstream of where land use or hydro-engineering interventions are made and these impacts can be negative as well as positive. The impact on poor people is that the models facilitate scientifically informed decision-making and scenario-based analysis of the likely (intended and unintended) consequences of actions meaning that policies or management strategies are tested *in silico* (and their benefits weighed against their negative impacts) before being tested *in vivo.* This has the potential to improve land and water management for sustained production of high quality water in the uplands for consumption by water-needy lowland communities.

It is also clear that the kinds of technical models outlined here are best if they are designed to be policy-focused rather than research focused. The characteristics of science-focused and policy focused models are rather different :

Research models	**Policy models**
Research problem well defined as hypothesis which model addresses	Policy problem ill-defined, model more generalized
accurate representation of processes	adequate representation of processes
complexity and (time and space) resolution reflect processes	complexity and (time and space) resolution reflect data
accurate representation of spatial variability	adequate representation (existing data)
Sectoral and detailed	Less detailed but multi-sectoral (integrated or holistic)
scientifically innovative	scientifically proven
raises more questions than answers	provides simple(?), definitive(?) answers
interesting and worthwhile in its own right	interesting and worthwhile only through its output
process centred	input/output centred
numbers validatable	outcomes validatable
as complex as necessary	as simple as possible
as fast as possible	faster (no more than a few minutes running)
data hungry, if necessary.	data lean.

Table 1 The characteristics of research versus policy models (from Mulligan, 2004) [1]

Furthermore, models are much more likely to be used if (a) their value is clear and they provide the information required (b) they have many of the characteristics defined under policy models in table 1, (c) they are supplied with all of the necessary data required for their use in a particular region, (d) they require little specialist knowledge to use, (e) results are accurate, believable and easily interpretable and finally (f) they can be obtained freely, are actively supported and improved and can be run without expensive software or hardware.

[1] Mulligan, M., 2004. *MedAction, Development, testing and application of the climate, hydrology and vegetation components of a*

Desertification Policy Support System, Final report for work undertaken as part of 'MedAction: Policies to combat desertification in the Northern Mediterranean region', EU-DGXII (contract EVK2-2000-22032): Brussels.

Impacts On Poverty

E. Impacts on poverty to date

20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

No such impact studies have taken place though undoubtedly water poverty is a serious issue in areas of the lowland humid tropics, which could be much improved by better management of upland catchments. Moreover much work has been done on the efficacy of PES schemes (see for example project R8174) and their ability to improve the livelihoods of resource poor but water rich communities in the tropical montane hillsides. Such schemes, if properly managed, could well have benefits for (a) reducing the economic poverty of agriculturally marginal montane communities, (b) reducing the water poverty of (especially subtropical) lowland communities whilst (c) also preserving elements of biodiversity and ecosystem function and (d) reducing land and soil degradation.

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical and, financial) of the livelihoods framework;*
- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

This question is very difficult to provide data for since the types of tool developed here contribute to policy formulation at a range of scales and separating the direct impact of such policies from other variables including changing market prices for commodities, climate variation and change, soil degradation effects, development, aid and other policy effects is impossible. Since there is not a controlled 'baseline' against which to measure impacts of this tool on policy and impact of policy on poverty, impact cannot be measured. However, it is now well accepted that (a) reliable high quality water supplies are critical to development and poverty reduction, (b) water and land use are connected in complex ways and mis-management of land use can have serious downstream impacts on the availability and quality of water, (c) management can be improved if it is based on good science rather than propagated 'myths' (see FMTT for example), (d) good science is much less useful in management unless it is also locally relevant and driven by local information. Since the FIESTA approach combines good

science with local application it provides better information for management and can be expected to have positive effects even if these are difficult to disentangle from all of the other factors that combine to determine poverty. In other words, the science and logic dictates that there should be an impact but the measurement of that impact would be rather difficult given all of the other variables that determine changing poverty in a region.

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

Environmental benefits include reduced forest loss in tropical mountains accruing from better hydrological valuation of the water resources for downstream consumption produced by these systems. This hydrological valuation will form the basis for better-informed PES schemes providing a monetary value for forests that have less apparent value in carbon sequestration than lowland tropical forests have and thus in many cases have their greatest tangible value as poor quality pasture. These forests are nevertheless extremely valuable in terms of providing water, slope stability, reduced landsliding, soil degradation and other geomorphic hazards as well as maintaining high levels of biological diversity and species endemism - all services that are very difficult to quantify in economic terms but with clear environmental benefits on-site and downstream. Many of the remaining biological hotspots occur in montane forest areas, yet deforestation in these areas is occurring more rapidly than in the lowland forests.

In addition to reduced forest loss, improved land and water management will lead in many cases to improved dry season flows, erosion and fluvial sediment loads fostering improved downstream aquatic and riparian environments of importance to fishing communities.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

If used properly there should not be. Unlike with the application of simple hydrological rules of thumb, the information provided by the FIESTA approach is locally relevant and locally appropriate. Thus any negative impacts of a particular land use policy being tested as a scenario (under current or future climates) should be apparent in the model output. Once observed as having negative impacts *in silico,* this policy is likely to have those same impacts *in vivo*. Thus, if adverse impacts do occur they will occur with prior knowledge and hence the policy-maker will have made a judgement that such effects are acceptable given other benefits.

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of

natural disasters and increase their resilience? ***(max 200 words)***

Yes, because the tools focus on understanding the impact of projected climate change on water resource availability so that policies can be implemented with some knowledge of the likely trajectories for water resource change to result from climate change thereby facilitating some degree of preparedness and the potential for the development of adaptation or mitigation strategies. Moreover the best protection against the effects of climate change in dry or seasonally dry lowlands in the tropics will be, in many cases, to find ways to maintain the careful management of upland montane forests for their significant provision of high quality water.

Better appreciation of the provision of water by tropical uplands now and in the future is one of the key contributions of the FIESTA approach. Well-managed and forested uplands supported by PES from downstream dependents is also a good protection against all but the most serious of flood events. The most serious flood events are rainfall magnitude and geomorphologically controlled and thus cannot be prevented by any means other than not populating affected areas, though they could be better predicted for mitigation of impacts (through improved evacuation and emergency planning).